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FHWA/IN/JHRP-87/2 - 2

BEHAVIOR OF MUCKS AND AMORPHOUS
PEATS AS EMBANKMENT FOUNDATIONS

Timothy Crowl and C. W. Lovell



PURDUE UNIVERSITY



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EXECUTIVE SUMMARY

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To: H. L. Michael, Director
Joint Highway Research Project

May 26, 1987

From: C. W. Lovell, Research Engineer
Joint Highway Research Project

Project: C-36-5P

File: 6-6-16

Attached is a Final Report on the study, "Behavior of Mucks and Amorphous Peats as Embankment Foundations". The report is written by Timothy Crowl and C. W. Lovell.

These materials of very low shear strength and very high compressibility are seldom used as embankment foundations. However, the research proposes a technique for successful use for low embankments (± 10 ft), where loading is in stages.

Stage height is controlled by suitable safety against bearing failure, lateral squeezing, embankment spreading, and rotational sliding. Strengths are determined at any stage of the construction by field vane shear measurements. Stage duration is determined by field pore pressure measurements.

Settlement prediction is produced by: laboratory creep tests, the Gibson-Lo model, and previous correlations between laboratory and field settlement measurements. Surcharge loading is usually required before a pavement may be placed on the embankment.

Examples of the proposed method are included, both with and without the inclusion of geotextiles.

The report is submitted for review, comment and acceptance in fulfillment of the referenced study.

Respectfully submitted,



C. W. Lovell
Research Engineer

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EXECUTIVE SUMMARY

BEHAVIOR OF MUCKS AND AMORPHOUS
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by

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16. Abstract The construction of highway embankments over deposits of amorphous peat and muck is made difficult by the low shear strengths, high compressibilities, and excessive amounts of creep typically associated with soils of this nature. This report begins with a review of the compression behavior of these soils, including a method for predicting embankment settlements from the results of laboratory tests. A soil testing program is then developed for the determination of parameters required for embankment design and construction. Field vane shear tests are recommended for the measurement of the undrained shear strength, and creep tests are recommended for calculation of the parameters required for settlement prediction. The report concludes with the presentation of a procedure for design and construction of embankments over amorphous peats and mucks. The procedure relies upon the use of stage loading, preloading, and in some instances geotextiles, to overcome the problems ordinarily encountered during construction over such soft soils. Design examples illustrating this procedure are provided.					
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EXECUTIVE SUMMARY REPORT

Introduction

A large number of deposits of amorphous peat and muck are located within the State of Indiana. Many difficulties are encountered when highway embankments are constructed over these soft soils. In the past, highway engineers have relocated roadways to avoid construction over peat or muck. In other instances, the organic material was excavated and replaced with a more suitable material. However, neither of these methods is economical by modern standards, forcing highway departments to develop more sophisticated methods which allow construction directly across deposits of such materials.

Two characteristics associated with amorphous peats and mucks make them undesirable as materials for embankment foundations. Materials of this nature compress excessively when they are subjected to an applied load. A large portion of the compression is a result of the relatively high amounts of secondary compression associated with organic soils. These deformations occur over a long period of time, which compounds the problem. Deposits of these materials possess low preconsolidation pressures, so a large

compression response is likely even at low stress levels. Amorphous peats and mucks are also characterized by very low shear strengths. Shear failures, which are both expensive and time consuming to renovate, can occur very easily either during or after construction. Deposits of amorphous peat and muck are highly variable, so that representative values of compressibility and shear strength are difficult to define.

As a result of these typical characteristics, efforts to construct highway embankments over these materials have often resulted in poor performance in the form of excessive total settlements, large differential settlements, and shear failures. In addition, attempts to predict embankment settlements from the results of laboratory tests are often unsuccessful.

The recently completed project was initiated to allow the development of a procedure for the design and construction of low embankments (± 10 ft) over amorphous peat and muck. The project was completed in two parts. A draft interim report, written by Joseph (1986), provided a very theoretical approach to the problem at hand. However, the report lacked a simple procedure for design and construction. The project was therefore extended to permit completion. The recently submitted report by Crowl & Lovell (1987) finishes the project by providing the requested procedure.

Part 1-Joseph

The first topic covered by Joseph (1986) was the need for a classification system for peats and mucks in geotechnical engineering. It was felt that the wide variation in the behavior of soils with different organic contents contributes to the confusion that develops when comparing the response to loading at different sites. To help reduce this confusion, Joseph presented a unified system for classifying peat based on existing methods. The steps in the von Post system and the ASTM system were combined to provide a more complete method of classification. The use of fuzzy sets was recommended to reduce the scatter resulting from human uncertainty when using the classification system.

Joseph then discussed site investigation, sampling, and sample preparation. The variability typical of deposits of organic soil makes it rather difficult to obtain representative values of soil characteristics. Joseph recommends making a large number of simple and inexpensive tests on samples obtained within the area of interest. The results of water content tests, ash content tests, and possibly oedometer and shear strength tests can be used to locate the worst conditions at the site.

The compression behavior of mucks and amorphous peats was then studied to aid in improving the accuracy of settle-

rounding soil. However, this is not true, as the unit weight of the embankment material is normally greater than that of the foundation soil. The second misconception is that the bearing capacity is increased by the tensile strength of a root mat. The strength contribution of the mat is negligible, and any support provided by the mat will decrease with time as the mat yields and weakens.

The use of a surcharge has been included in many projects over soft clays. Surcharging consists of placing a load in excess of the final embankment height to accelerate compression. A surcharge will increase the soil strength, and reduce the compressibility and long term secondary compression. Once the desired settlements have occurred, the excess load can be removed.

Next, Joseph applied the yield envelope concept for use during the construction of embankments, using techniques of stage loading and surcharging. In general, when placing the first stage load, a significant strength gain will occur only if the stress level exceeds that of the preconsolidation pressure. A strength gain will not develop for lesser stress levels, as the existing strength is controlled by the preconsolidation pressure.

Joseph also investigated the use of berms, sand drains, and lightweight fills during construction over soft soils.

ment predictions. A problem associated with the settlement prediction of embankments constructed over peat and muck is the nonlinear e -log p relationship exhibited by these soils, as well as the large amounts of secondary compression. The Terzaghi theory is not applicable for organic soils because of these deviations from clay behavior. In addition, the Terzaghi theory is only valid for infinitesimal strains when the change in permeability can be neglected.

The question of nonlinear finite strain consolidation was then examined. Two models, the Berry-Poskitt theory and the Mesri-Rokshar theory, were observed to predict laboratory behavior sufficiently. However, these models were not practical for field situations as a result of the variation between field and laboratory behaviors. The extent of field investigation necessary for suitable predictions can be justified for test fills, but is not practical for every day construction. It was therefore concluded that a simplified model would be acceptable for estimating settlement.

Joseph conducted a laboratory testing program on three organic soils sampled in Indiana. The testing program consisted of consolidation tests, creep tests, permeability tests, and shear strength tests. Consolidation tests produced a non-linear e -log c curve as expected. Creep tests provided a linear e -log t relation. The creep test results were used with the Gibson-Lo model for settlement

prediction. Joseph felt that this model was suitable for embankments over peats and mucks if final embankment heights are not large, and if the surcharge stress is not greater than approximately twice the final stress level.

K_0 triaxial tests were also performed, and although index tests indicate a high variability, the shear strength was found to be reasonably constant. The results of these tests produced a unique failure envelope in $p'-q$ space.

Emphasis was then placed on various construction methods used when constructing embankments over organic soils. The three approaches covered were displacement, floatation, and surcharging. Displacement involves replacing the peat or muck by a material of more desirable quality. The most efficient method requires the removal of a 5 to 10 foot wide strip of the root mat, usually by blasting. A more suitable material is then end-dumped over the strip. The embankment material then settles and displaces the soft organic soil. This method is not popular as it is costly, untidy, and unsafe.

Floatation consists of placing the embankment on a supporting base layer. This layer may be the root mat, a geotextile, a layer of tree trunks, or a combination of these materials. There are two misconceptions regarding this method. One is that the road is buoyant on the sur-

For amorphous peat and muck, berms were found to play a useful role in increasing embankment stability, particularly if the underlying soil is soft. Berms will reduce the occurrence of undrained movements, therefore limiting the magnitude of shear deformations. Construction of berms is optimized by simultaneous placement from both outer edges inwards. This sequence will induce lesser shear stresses, and has the advantage of trapping any mudwave that develops in the center.

Vertical drains are usually not required in peats as a result of the relatively high permeabilities that exist. This is true for mucks as well, except for clayey mucks which possess a low in-situ permeability. Joseph felt that the beneficial aspects of sand drains are derived mostly from the pile-like action of the sand columns. He concluded that sand drains are unlikely to be useful, except possibly when there are underlying soft soils of low permeability.

Lightweight fills such as sawdust, wood waste, and compressed bales of peat have been used to help overcome settlement problems. The reduced applied load will induce less settlement. To prevent decomposition, the fill should not extend above the groundwater table. In general this technique is used only for minor roads.

As previously stated, the report written by Joseph does

not present a simple procedure for design and construction of embankments over amorphous peats and mucks. Consequently, an extension of the study was granted to permit the development of such a procedure. Work was continued with this goal in mind by Crawl & Lovell (1987).

Part 2-Crawl & Lovell

The report by Crawl & Lovell investigates the difficulties associated with settlement prediction for organic soils. As a result of work performed by Gruen (1983) and Joseph (1986), the Gibson-Lo model was chosen for settlement prediction. This model was found to be as accurate as others, yet was easier to use.

The poor accuracy often achieved with settlement predictions is mainly the result of the difference between laboratory and field conditions. The parameters required for the Gibson-Lo model are obtained from the results of creep tests performed in the laboratory. Tests conducted in the laboratory allow only one-dimensional vertical deformations, while lateral deformations can occur in the field. Other conditions in the field such as snow load, variations in water table, and the presence of a soft clay layer beneath the organic soil affect the compression behavior.

During research conducted by Edil & Mochtar (1984), the laboratory and field behavior of organic soils under loading

were observed. The results were compared to determine if there were any existing relationships between the two conditions. From this comparison they were able to develop correlations between the model parameters for laboratory and field performance. These correlations relate values of primary compressibility, secondary compressibility, and the rate factor for secondary compressibility. Using these corrections, fairly accurate settlement predictions have been achieved by other researchers.

Another topic examined was the use of geotextiles during the construction of highway embankments over amorphous peat and muck. It was concluded that geotextiles provide a number of benefits during projects of this nature. Geotextiles will reduce lateral deformations, provide an increased bearing capacity, increase rotational stability, and reduce differential settlements. Intermixing of foundation and embankment materials is eliminated as a result of the barrier formed by the geotextile.

After the preliminary literature review, a soil testing program for use during design and construction was outlined. Laboratory creep tests were recommended for determination of parameters required for the Gibson-Lo model. K_0 triaxial tests were also performed for determination of the undrained shear strength. However, when the results of the K_0 triaxial tests were used in design analyses, a number of problems

developed, as discussed in the report. In addition, the equipment required for such testing would need to be custom made, and would be very costly. As a result, field vane shear tests were performed to eliminate the need for the triaxial tests.

A procedure for the design and construction of highway embankments over amorphous peat and muck was then presented. The first step in the procedure is a site investigation for determination of representative soil characteristics. Disturbed samples can be taken for determination of the water content, organic content, and specific gravity. Creep tests should also be performed for determination of compressibility characteristics. Field vane shear tests should be conducted throughout the site at various depths to determine the undrained shear strength.

The depth of the amorphous peat or muck in the region of the proposed embankment can be determined using ASTM Standard Specification D4544-86. Soft clays or marls often underly the amorphous peat or muck and can influence the behavior of the constructed embankment. These materials should be sampled as well until a layer of adequate strength is reached.

Once an initial embankment geometry is decided upon, embankment design can begin. Design procedures for both

unreinforced and geotextile reinforced embankments are provided in the report. During the design stage, a number of analyses must be performed to calculate the factor of safety with respect to the overall bearing capacity, resistance to lateral squeeze, embankment spreading, and rotational stability. For geotextile reinforced embankments, additional analyses must be performed to calculate the required tensile strength and modulus of the fabric.

The soft nature of amorphous peats and mucks often makes construction to the final embankment height in one stage impossible. Stage loading will therefore be required. From the results of the preceding analyses, the maximum first load can be applied, and the foundation will begin to consolidate. The consolidation will result in a strength gain allowing further loads to be placed without inducing failure in the embankment foundation.

To determine the duration of each stage load required for consolidation to occur, pore pressure transducers should be placed in the foundation. Once excess pore pressures induced by the previous loading have dissipated, no further strength gain will develop. Field vane shear tests should then be performed in the foundation beneath the embankment, and in areas adjacent to the embankment to determine the extent of the strength gain. Using the increased values of undrained shear strength, the aforementioned analyses should

be performed to calculate the allowable height of the second stage load. This procedure of applying the load, allowing pore pressures to dissipate, measuring the increased shear strength, and placing subsequent loads should continue until the final embankment height is reached.

One of the problems associated with the construction of highway embankments over these materials is the large amount of secondary compression taking place over an extended period of time. To reduce the amount of settlement that occurs during the service life of an embankment, a surcharge in excess of the final design embankment height should be placed. The necessary height of surcharge is found by first using the Gibson-Lo model to predict settlements induced by the design height of the embankment. The input parameters required for this model are obtained from the results of creep tests. In order to obtain the most accurate results, creep tests should be performed at stress levels simulating actual field loading, rather than using conventional load increment ratios.

Then, using the previously mentioned correlations, the parameters obtained from the laboratory tests are corrected for field conditions. Using these corrected parameters, settlement prediction can now be conducted using the Gibson-Lo model. From the results of the settlement prediction, the amount of settlement expected within the service

life of the embankment can be found. The objective of the surcharge is to induce that amount of settlement during the time required for primary consolidation. To calculate the height of surcharge required to accomplish this, the Gibson-Lo model should be used to predict the settlement induced by various heights of surcharge until the appropriate value is obtained. The results of creep tests simulating loading by the design embankment height may be used as long as the stress increase of the surcharge plus the embankment is less than twice that used during these tests. Examples illustrating the design of unreinforced and geotextile reinforced embankments are provided in Appendix D of the report.

To observe the behavior of the constructed embankment, a number of field measurements should be made. Settlement plates should be placed for measurement of the magnitudes and rates of settlement. Inclined meters are recommended to measure any lateral movements of the embankment. As previously mentioned, pore pressure transducers should be installed to observe the dissipation of excess pore pressures.

The recommended procedure concludes with the presentation of a construction sequence for embankments over soft subsoils. Construction should begin by placing a working platform on the foundation soil for construction mobility

and easier placement of the geotextile if one is used. If geotextiles are to be used, they should be placed on the working platform, transverse to the alignment of the embankment. After placing the embankment to a height of one foot, the geotextile should be folded back on top of this material, and anchored by compacting the earth above the folded region. The core of the embankment is then placed and compacted. Subsequent lifts should then be constructed by placing and compacting the edges, followed by placement and compaction of the embankment core. Compaction lifts should be kept at about the same level, to aid compaction by lateral constraint.

Conclusions

The completed project has investigated the behavior of amorphous peats and mucks as embankment foundations. As a result of this project, a procedure for design and construction of low embankments (± 10 ft) over such soft soils has been developed. It is felt that stage loading will be necessary to construct embankments to final grade. Preloading can be utilized to accelerate settlement, reducing the amount taking place during the service lives of embankments. This report also presents a method for making more accurate settlement predictions for organic soils, using empirical correlations between laboratory and field behavior.

It is hoped that the recommended procedure will allow construction to be completed within one construction season. A test fill instrumented with pore pressure transducers, inclinometers, and settlement plates should be constructed to verify the usefulness of the recommended procedure.

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